a result, a precision of less than 0.2% was achieved for the difference in THz absorption coefficient. The THz absorption spectroscopy results supported her theoretical hypothesis that proteins influence not only single water molecules at the protein surface but also the hydration dynamics in their surroundings up to a distance of 10–15 Å, that is, 3–5 hydration shells. "We pioneered kinetic THz absorption during enzymatic catalysis. A gradient of water motions towards functional sites of proteins (recognition sites) is observed — the so-called hydration funnel," she explained.

Matthew Swithenbank of the University of Leeds in the UK is also studying THz spectroscopy in water, but with different technology — using on-chip THz time-domain spectroscopy. The approach combines a microfluidic channel and a planar Goubau line (PGL) that is formed by a single rectangular-shaped conducting wire lying on a flat dielectric substrate. However, it was a far from easy task, because microfluidic channels introduce impedance-mismatched interfaces at locations where the channel crossed the transmission line. These interfaces generated THz-frequency reflections in the time-domain, which at best complicated, and at worst prevented, subsequent analysis.

To avoid this problem, he fabricated a PGL on a 50-μm-thick polyimide film and positioned a microfluidic channel on the underside of the film for through-substrate measurement of liquid samples. This allowed total coverage of the transmission line sensing region (thereby eliminating time-domain reflections). He demonstrated that this technique was sufficiently sensitive to discriminate easily between alcohols in a homologous series that differed only by a single CH_2 group. "We are now poised to explore a range of solvent-based biochemical systems," he told *Nature Photonics*.

The next IRMMW-THz will be held in Copenhagen, Denmark over 26–30 September 2016. ❐

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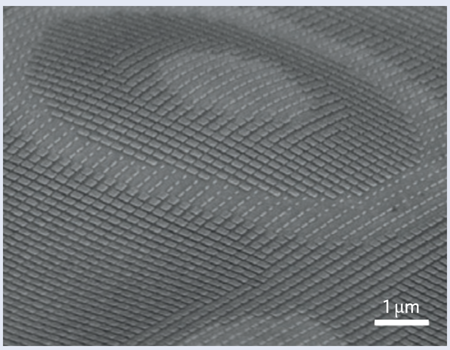
METAMATERIALS

Skinny cloak

Structures to render objects invisible to optical waves have been investigated extensively, but all implementations so far have limitations. Three-dimensional cloaks that use conformal mapping and refractive index profiles to guide light around objects pose challenges due to the sometimes drastic indexes required. And scaling up the fabrication of cloaks to macroscopic scales remains a challenging engineering problem. So-called carpet cloaks have also been previously implemented to mask an object hidden under a 'bump' on a plane, but the approach has geometry restrictions and still requires a bulky external cloak region.

Now, Xingjie Ni and Zi Jing Wong and colleagues from the University of California at Berkeley have reported a new type of reflection cloak with a subwavelength thickness (*Science* **349,** 1310–1314; 2015). The structure hides an arbitrarily shaped object (with an area of 36 μm × 36 μm in this case) from 730 nm wavelength light using a structure that is only ~100 nm thick. When light reflects from the surface it appears to have rebounded from a flat surface.

Whereas previous designs typically manipulate the optical path as waves propagate through the bulk region surrounding the hidden object, here the team implemented a single layer of thin plasmonic nanoantennas placed directly onto the object surface, which adjusts the phase — that is, cloaks — in one step upon reflection. By locally tailoring the phase response of the resonators it is possible to compensate for the phase variation (relative to a flat surface) due to reflection from the object surface. If one knows the local height of the object relative to the flat surface and the direction of propagation and the wavenumber of light in the surrounding medium, it is simple algebra to calculate the local phase variation induced by the object's presence. Then one places resonators whose phase response locally compensates for the variation.



AAAS

The team simplified the problem by restricting themselves to six antenna geometries, offering phase responses of 0, π/3, 2π/3, π, 4π/3 or 5π/3. They carefully adjusted the lengths of two sides and chose the combination of values providing 84% reflectance for each geometry (phase response) to avoid uneven reflection that would be detectable in the far-field.

The cloak itself consists of a Au coating covering the entire surface followed by a 50-nm-thick MgF_2 dielectric spacer layer and then the array of 30-nm-thick Au rectangles with locally varied side lengths. A bottom Au coating across the entire surface, which forms part of the resonator structure, improves performance and simplifies the problem (one can ignore variation of properties of materials underneath this Au layer). This coating only needs to be sufficiently thick compared with the skin depth (~20 nm in this case) of light in the metal at the considered wavelength.

The idea does have some limitations due to the nature of the structures employed. In particular, the phase response of the resonators naturally depends on wavelength and thus the design works ideally only at a particular wavelength of the incoming probe light. The response of the resonators also depends on the light's polarization (or equivalently, particular orientations of the sample with respect to the incident beam). Nevertheless, the fabrication and performance achieved here is inspiring and the thin cloak concept could be more readily scaled-up to macroscopic cloaking applications than bulk three-dimensional proposals.

"Next we can look at ways to scale up. I believe nanoimprinting can be used to make the structures on a macroscale," Xiang Zhang, corresponding author of the manuscript, told *Nature Photonics*. "Another direction is looking for ways to achieve an ultrathin transmissive cloak. This ultimate cloak would be a cream or spray to apply to your body, making you disappear — this calls for isotropic metamaterials with unique properties, made by self-assembly in a large quantity. However, this is yet to come."

DAVID PILE